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The Use of Computers for Solving Problems in Support of the Air Defense of Troops (Based on the materials of exercises and war games)

by

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In organizing the air defense of troops one is faced with the task of solving a series of logic and analytic problems. The more complicated of these include the selection of an optimal grouping of air defense means and evaluating their combat effectiveness.

The question of selecting the optimal grouping of air defense means arises most noticeably in planning to repel the first enemy air strike and to conduct large-scale regroupings of troops in the course of combat operations.

The effectiveness of a grouping of air defense means depends primarily on the quantitative and qualitative characteristics of their armament and combat equipment, as well as on the composition of the enemy's air forces and the methods of use of air attack means. Considerable difficulties are involved in making the correct decision on the disposition of a grouping of air defense means due to the large number of possible variants of operations and an insufficient knowledge of the results of their employment.

The mathematical calculation of the effectiveness of a grouping usually serves as the criterion for evaluating a decision. The manual method of calculation as well as calculations performed with keyboard calculators give a general, approximate result which permits only a comparative evaluation of different groupings. This is explained by the fact that the manual solution of a problem such as a complex mathematical model of a strike by air attack means cannot practically be performed to its full extent. In view of this, the formula for evaluating the effectiveness of combat operations by air defense means by the manual method of calculation has been greatly simplified, and as a result certain limitations have been artificially placed upon the accuracy of the results obtained. The use of computers for this purpose makes it possible not only to find the optimal variant of the grouping of air defense means for the accepted estimate of the importance of targets being covered, 50X1-HUM to determine the quantitative indicators of combat effectiveness.

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In the Leningrad Military District a number of exercises and war games have been held in which studies were made of the use of computers for the automation and mechanization of the control of troops and to perform various labor-consuming computational tasks both in the planning of front operations as well as in carrying out such operations.

Calculations were made on the URAL-4 stationary general-purpose computer at the computer center of the Leningrad Military District.

The following problems were solved on the URAL-4 computer in support of the air defense of troops:

-- calculation of the effectiveness of the air defense fighter aviation;
-- calculation of the effectiveness of a grouping of surface-to-air missiles;
-- calculation of the movement of the air defense units of a front during an operation.

A total of 15 variants of the problems were solved.

The problem of evaluating the effectiveness of the combat employment of the fighter aviation in support of the air defense of a front was treated most fully in the exercises. The solution of this problem on the URAL-4 computer was worked out by one of the scientific research institutes.

The permanent data stored in the computer memory are the tactical-technical characteristics of different types of aircraft and the coefficients which determine the effectiveness of the combat employment of the aircraft and its armament by element.

The variable data are:

-- flight conditions (day or night, weather conditions, use of maneuvering and jamming);
-- flight altitude (low, medium and high, stratospheric);
--the number of one's own fighters and fighter-bombers by type;
-- the number of enemy aircraft by type.

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Preparation of the problem consists of a precise accounting of the air forces of both sides by types of aircraft and the conditions of the attack. On the average, approximately 50 minutes are required to prepare the initial data, not counting the time spent on collecting data on the complement and basing of a grouping of the attacking aviation and one's own fighter aviation. Machine operating time is four to five minutes. The result is printed on telegraph tape and on an automatic digital printer in the form of four-digit groups.

A procedural entry is printed at the beginning and end of the message.

The total time required to solve a problem from the moment that the preparation of initial data begins until the time that the processed data are finally received is determined basically by the load on the communications channels and averages three to four hours, which is fully acceptable for the present stage of computer application.

This same problem was solved on a keyboard calculator at the computer station of the district staff using a method developed by the Kiev Higher Artillery Engineering School i/n Kirov.

For comparison purposes, calculations were also performed using a formula for the mathematical expectation of the number of targets destroyed:

$$M_{exp} = S \times K \times P_d ,$$

where S is the total number of aircraft in a grouping of the front fighter aviation;
K is the coefficient of combat readiness of fighters in the grouping (0.9);
P_d is the probability of destroying one enemy aircraft.

Further,

$$P_d = P_{gui} \times P_{at} \times P_{des} \times P_{nd} \times K_{rad} \times K_{tr},$$

where P_{gui} is the probability of guiding the fighter to the target;
P_{at} is the probability that the fighter will attack the target;
P_{des} is the probability of destruction of the attacked target;

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P_{nd} is the probability that the attacked target will not be destroyed by the fighter;
K_{rad} is the coefficient of electronic countermeasures;
K_{tr} is the coefficient of technical reliability.

As an example, let us consider the results of the solution of the above problem obtained on the basis of a computation of the effectiveness of the grouping of air defense fighter aviation in a front zone to repulse a strike by the tactical aviation of the "West".

The possible number of attacking aircraft is 165.

The number of air defense fighters used to repulse the attack is 318 of which 87 percent are all-weather fighters. The attack may be carried out during either the day or night.

Up to 75 percent of the attacking aircraft can use various types of maneuvers, and up to 40 percent can make the flight at low altitudes.

For the given grouping, the probability of shooting down one enemy aircraft P = 0.67 x 0.85 x 0.73 x 0.82 x 0.7 x 0.9 = 0.214.

The results of a solution of the problem:

a) On the URAL-4 computer

Day attack

The expected result of destroying enemy aircraft:

-- at low altitudes, 19.3 percent (13 aircraft);
-- at high altitudes and in the stratosphere, 36.7 percent (36 aircraft).

Final result, 29.7 percent (49 aircraft).

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Night Attack

The expected result of destroying enemy aircraft:

-- at low altitudes, 10.7 percent (seven aircraft);

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-- at high altitudes and in the stratosphere, 31.5 percent (31 aircraft).

Final result, 23.0 percent (38 aircraft).

b) On a keyboard calculator

Under any conditions the expected number of destroyed aircraft is 57 (34.5 percent of the total number of attacking aircraft).

c) Using a manual method

M_{exp} for a daylight attack = 61 aircraft (37.0 percent)
M_{exp} for a night attack = 61 x 0.87 = 53 aircraft (32.2 percent),

where 0.87 is the percentage of all-weather fighters.

From a comparison of the results it is obvious that the results obtained with the URAL-4 computer are more complete and make it possible to consider not only the flight conditions of the air enemy but also the quantitative and qualitative characteristics of engaging the enemy with a grouping of air defense fighter aviation of a front. In absolute values these results are closer to actual values since they take into consideration a much larger total of mutually related factors which determine the conditions of combating an air strike, as well as the qualitative characteristics of the aircraft of both sides.

The disadvantage of using keyboard calculators for solving the problem is the poor precision of the results due to a simplified consideration of patterns of attack and also as a result of the fact that certain input values, such as the distance from the home airfield and the corresponding limits of target interception from the front line, the range of target detection and the distances to ground guidance posts represent particular characteristics of certain components of the front aviation and not of the entire grouping of the front fighter aviation (the grouping of air defense fighter aviation in its initial position). Use of the averaged values of these special characteristics results in a significant divergence of the output data for the entire grouping as a whole. 50X1-HUM

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The use of manual methods of computing the mathematical expectation of destroying air targets by fighter aviation gives only approximate results which will differ from those obtained by other methods to the extent that a greater number of averaged values are used to represent the coefficients comprising the mathematical basis of the formula.

Certain shortcomings were found in solving this problem on the URAL-4 computer: in particular, the output data from the computer must be transformed by introducing a certain percentage of low-flying aircraft which is not taken into consideration in compiling the initial data, and the results for each particular altitude as well as the final result must be converted to absolute values.

A shortcoming of the algorithm of the problem is that it does not take into consideration the duration of the attack and possible losses by one's own fighter aviation due to enemy fire. This has a significant influence on the estimate of the effectiveness of the combat employment of the fighter aviation in support of the air defense of a front.

The effectiveness of the combat employment of surface-to-air missile units was also computed by three methods--on the URAL-4 computer (the problem was worked out by the Kiev Higher Artillery Engineering School i/n Kirov), on a keyboard calculator and by the manual method.

Solution of the problem using the computer gave an unsatisfactory result -- the destruction of from zero to six percent of the total number of targets passing through the zone of fire. In our opinion the reason for such understated results of the effectiveness of the grouping of surface-to-air missile units is an improper mathematical modeling of the control of this grouping (only centralized fire control was considered) and the understated value that was used for the coefficients of effectiveness of different components of the systems during combat. A mathematical model of an attack by an air enemy requires the input of a large number of probability characteristics as initial data, which are not readily available to the officer-operator who is solving the problem. It would be more advantageous if the basic parameters characterizing the mathematical model of the attack were included as permanent information for the problem. This problem should be worked out more thoroughly.

The result of solving this problem on a keyboard calculator was the destruction of from 10 to 20 percent of the targets passing through the zone of fire. The mathematical result is determined by using a model of an attack by an air enemy as the basis for the calculations.

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The use of the URAL-4 computer to solve the problem of moving the air defense troops of a front (army) in an operation (worked out by the Kiev Higher Artillery Engineering School i/n Kirov) was not very effective, and the practical use of the results is complicated for the following reasons.

The temporary characteristics which determine the start of packing up, movement, etc., in the problem, are closely tied to the rate of advance of the troops being provided cover, which in itself is not a constant and depends on many factors which are most frequently of a random nature. A change in the rate of advance leads to a complete breakdown in all parameters of a calculated movement timetable.

In our view the start of movement must be determined by a line, upon reaching which a firing element is removed from the firing position; it should not be determined by a time at which it is removed from the firing position.

The problem involves making calculations for only three subunits (firing elements). If there are more subunits in a unit, the problem must be solved by the method in which they are grouped, disregarding the organizational structure of the unit. This leads to an incorrect calculation of the coefficient of cover of the troops provided by a grouping of air defense means.

The use of computers for operational-tactical calculations presumes not only that optimal values of multivariant problems will be found -- a task which is practically impossible by the manual method, but also that the time required for other calculations relating to the combat employment of the troops will be shortened. The labor-consuming and unwieldy nature of the preparatory work substantially reduces the effects of automating the solution of this problem, since two to three hours are required to fill out the inquiry statement alone.

The reviewed results of solving problems in support of the air defense of the troops show that this work has already found its place in the practical operations of the staffs; a further improvement of its forms and methods is necessary.

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This pertains first of all to the process of modeling a problem. It is known that all operational-tactical problems are multivariant. In order to have at least an approximation of the values being sought, a number of formulas were derived, even before the appearance of the computer, which could be used to obtain single-value answers. This was made possible

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through the use of different types of averaged coefficients in the calculations.

Mathematical models of such problems have the following shortcoming: certain averaged values of a series of quantities (coefficients) are entered into the memory of the computer beforehand, and therefore, as a rule, the invariance of the machine solution is not great. For example, in a problem involving the estimation of the effectiveness of a grouping of air defense fighter aviation, invariance comprises not more than six solutions.

In compiling a model of an attack by air means it is best to consider those variants which will create the most complex conditions of combat. The machine solution must provide the conditions for the optimal solution of the problem.

Usually the solutions give the result of the destruction of air targets but do not make it possible to estimate losses experienced by the active air defense means as a result of the air strike. This leads to gross errors both in original as well as in subsequent calculations of the effectiveness of the combat employment of air defense means in an operation.

Practice gained in the use of computers for operational-tactical calculations has shown the need for greater uniformity in the method of making inquiry statements. Otherwise, the work of staff officers will be greatly complicated and will lead to a waste of time and errors in the calculations.

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